Manpower trends

Tomorrow's EE

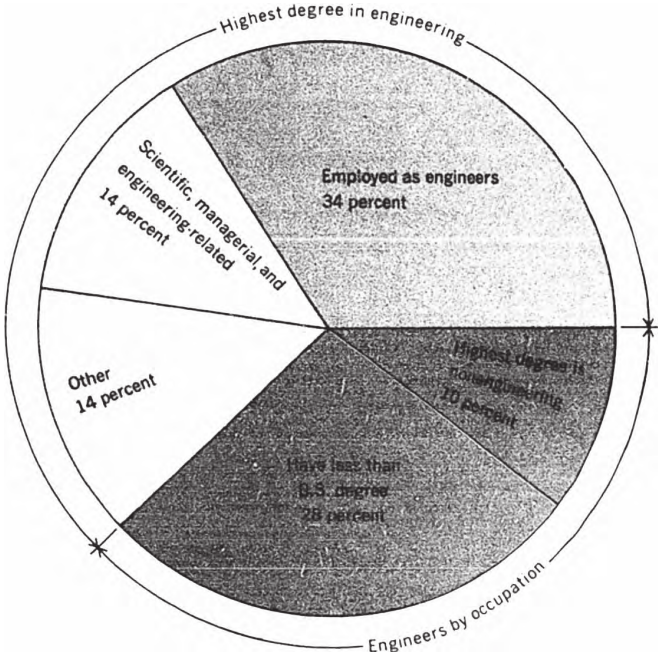
The engineer of the future may well be an M.S., a Ms., black, or a combination of all three

Engineering education in the United States is changing, and the changes it is undergoing will have significant and long-lasting effects on the engineering profession and on the types of service it will provide to society in the years ahead. The past four years have seen a sharp decline in engineering enrollments (which only now are beginning to level off), a growing movement to recruit more women and minority students into the profession, and a growth in programs to train engineering technologists. These changes mean, of course, an increase in the number of people receiving an engineering education, but beyond that they reflect a change in philosophy and in the type of education being offered. They promise to be as significant to the future of engineering in the U.S. as was the post-World War II shift from a technologically oriented engineering curriculum to one emphasizing the physical and mathematical sciences.

In other words, technological advances, increases in knowledge, changes in national priorities and funding patterns, and altering social conditions, as well as changes in the profession itself, have combined to affect the demand and requirements for engineering services. This change in climate, in turn, directly affects the type of education that engineers receive.

Lawrence P. Grayson
National Institute of Education

[1] Distribution of U.S. engineers by occupation and education as estimated by U.S. Department of Labor.



Employment and graduates

In 1972, the U.S. Department of Labor estimated that there were more than a million engineers employed in the United States (Fig. 1); this includes both persons with engineering degrees (although some of these are in other occupations but consider themselves engineers) and persons not educated as engineers but who classified themselves as such. Of the estimated total of 1 066 000, the majority are working in private industry, with Government and academic insitutions accounting for most of the remainder (Fig. 2).

Although employment patterns exhibit annual fluctuations, such as occurred in 1970–1971, the Department of Labor recently projected an increase in the demand for engineers to about 1.5 million by 1985. This 40-percent increase over the number employed in 1972 represents a 2.7-percent annual rate of growth, compared with an average of 3.7 percent per year from 1960 to 1968. Population growth and the resulting expansion of industry to meet the demand for additional goods and services are the principal factors underlying the anticipated increase in employment opportunities, and the requirements for new energy sources are also likely to increase this demand.

In addition to the 434 000 new engineers required for growth, nearly 245 000 will be needed to replace those who die, retire, or otherwise leave the labor force, and another 258 000 to replace engineers who transfer to other occupations. Thus, growth and replacement needs are expected to total about 937 000, or an average of about 72 000 additional engineers a year from 1972 to 1985.

New graduates are the principal source of additions to the engineering labor force, but replenishment also comes in the form of transfers from other occupations—including upgraded technicians, reentrants into the job market (such as from the Armed Forces), immigrants, and new graduates who did not major in engineering. Based on past patterns, an average of 27 300 nonengineering graduates can be expected to enter the profession annually between 1972 and 1985, leaving approximately 44 800 to be hired each year from among the new engineering graduates. However, recent studies by the Engineering Manpower Commission indicate that, since 1970, only 60–70 percent of engineering graduates with bachelor's degrees, 55–70 percent with master's degrees, and approximately 85 percent of those with doctor's degrees have been accepting engineering jobs upon graduation.

By applying the extremes of each of these ranges to U.S. Office of Education projections of the number of engineering degrees to be awarded each year, two projections of the number of new engineering graduates to be employed can be developed. For the period 1975–83, these projections (Fig. 3) are below the 44 800 new employees required annually—indicating a shortage of engineers for at least the next decade, although that shortage will depend on geographic location and area of career specialization.

One of the earliest indicators of graduate statistics is the career interest of first-time college students. From 1966 to 1971, interest in engineering careers declined about 40 percent, decreasing from 9 percent to 5.3 percent of entering students—at a time when the total number of freshmen entering college was increasing by 37 percent. If engineers are to be graduated in sufficient numbers to meet the requirements of industry, engineering colleges must attract a larger proportion of the entering freshmen; and yet it has been estimated that only about 4 percent of the 22-year-old population can be motivated to obtain the bachelor's degree in engineering and natural science. This factor makes the task of increasing engineering enrollments even more difficult.

Another trend is the increased tendency of engineering students to go on to graduate school, which delays their entrance into the profession. From 1960 to 1973, the number of engineering master's degrees awarded annually increased 147 percent, from 7159 to an estimated 17 700, and doctor's degrees rose 395 percent, from 786 to an estimated 3890. In the same period, the number of bachelor's degrees increased only 21 percent, from 37 679 to an estimated 45 510. The increases in graduate degrees are expected to continue during the next decade, although at a slower rate, but the number of bachelor's degrees awarded annually will decrease sharply, at least through 1976 (Fig. 4).

One offsetting factor should be the growth in engineering technology programs (see Box, p. 56). For many years industry has hired engineering graduates to fill positions for which less fundamental college-level curricula would provide more suitable preparation, thus resulting in the underutilization of many engineers. As more engineering technologists become available, and with the projected shortage of engineers, new graduate engineers will be offered positions of greater responsibility than were their 1960 counterparts.

However, the growth of these programs should not affect engineering enrollments. The reduced mathematics and science requirements for engineering technology, both as college prerequisites and as requirements for the bachelor's degree, open up a much larger pool of high school graduates as possible registrants.

The result of these trends—the reduced flow of baccalaureate engineering graduates into industry and the increased supply of engineering technologists—will be a reevaluation of what constitutes the minimum academic requirements for entering the engineering profession.

Minorities and women—an untapped source

Although the United States has made progress during the last decade with respect to equal opportuni-

Projection 1: There will be a shortage of engineers. It will begin to be felt in the next year or two, and will continue to the end of the decade and into the 1980s. The shortage will occur first in the industrial areas of product development, production, and manufacturing.

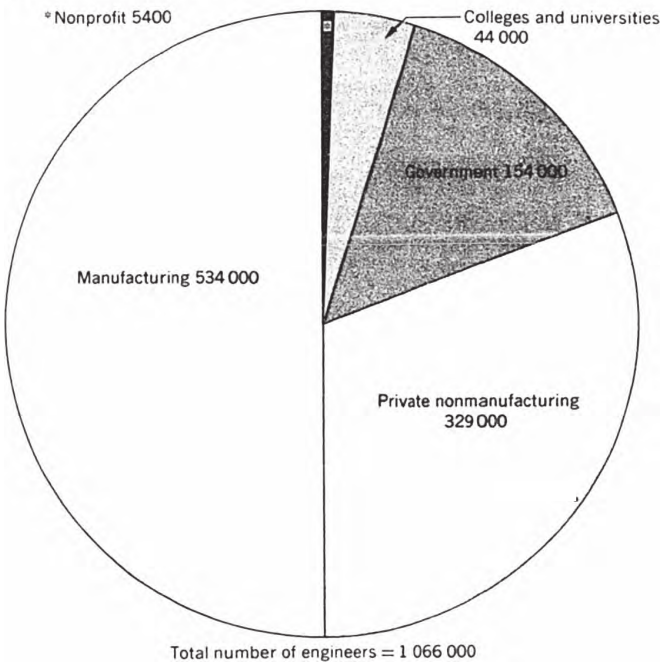
Projection 2: The number of bachelor's degrees awarded annually in engineering will decrease sharply for the next several years, through 1976, and then rise gradually for the remainder of the decade. This increase will be the result both of engineering programs attracting slightly more of the entering white male college students, and of more women and minority-group members selecting engineering as a career.

Projection 3: A higher percentage of engineering graduates will continue immediately into master's degree programs, with the percentage of such students reaching 50 percent by 1980.

Projection 4: Engineering technology programs will continue to grow rapidly, with the annual number of these graduates reaching one third to one half of the annual number of engineering bachelor's degrees awarded, by the end of the decade. The engineering technology graduates will continue to be sought by industry, particularly with the projected shortage of engineers, and thus they will ease, but not eliminate, the effects of that shortage.

Projection 5: By 1980, the master's degree will be considered the first professional degree in engineering—whether this is formally pronounced by the profession or becomes a matter of employment practice.

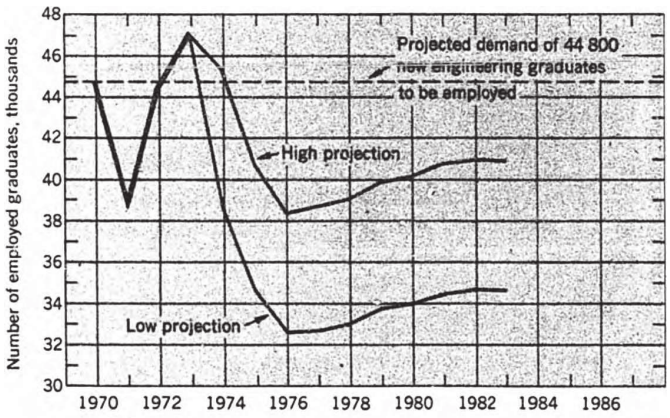
[2] Distribution of U.S. engineers by employment area.


*Nonprofit 5400
Colleges and universities 44 000
Government 154 000
Manufacturing 534 000
Private nonmanufacturing 329 000
Total number of engineers = 1 066 000

ties for employment and income, very few women and minority-group members have attained corporate-level positions. And the situation will not be rectified until greater numbers of women and minority students pursue engineering studies—since such training provides the main background for high-level managerial and professional employment in many industries.

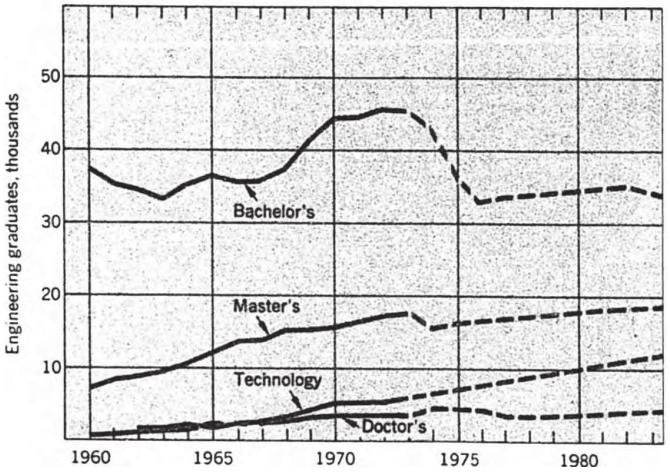
As potential engineers, the two groups face different problems, but there are also many historical similarities. Engineering has never been a "closed" profession, but the technical nature of engineering curricula, and the high level of sophistication in mathematics and science necessary to complete a B.S. program successfully, have discouraged many women and minority people from considering engineering careers. And women have had the added psychological obstacle of the traditional image of engineering as a man's field.

The 1970 United States Census classified 1 256 935 persons as engineers, of whom 14 955 are black and about 20 775 are women. The definition used in the Census, however, was very encompassing, so that many people without an engineering or technology degree were included in the classification. (The dif-



[3] Projected number of new engineering graduates employed, by year, for the period 1975–1980.

[4] Number of engineering and four-year engineering technology degrees awarded, by year, since 1960.



The engineering technologist

The need for technically trained manpower in U.S. defense industries during World War II provided a striking demonstration of the imbalance existing between the numbers of engineers and of their support personnel. To meet the critical shortage, the Federal government in 1940 created the Engineering Defense Training Program (which in 1941 became the Engineering Science and Management Defense Training Program, and in 1942 the Engineering Science and Management War Training Program). During the four years that these programs existed, more than a million persons were trained as technical assistants to release engineers, scientists, and industrial managers for higher-level technical and supervisory activities. The programs consisted of short, intensive in-service and preservice courses, given primarily by engineering colleges, for direct service to the war industries. Short-range solutions to meet an urgent need, they were not continued after the war.

The need still exists—but only in the last few years have institutions begun to develop programs to educate high-level technical support personnel in the form of engineering technologists. The distinction between a technologist and an engineer is that the engineer is viewed as one concerned principally with the development of new principles and methods, and with the management of engineering projects, whereas the technologist is concerned primarily with the application of established methods to specific problems. Based on a 1962 report of the American Society for Engineering Education, the Engineers' Council for Professional Development defines engineering technology as the part of the engineering field that requires the application of scientific and engineering knowledge and methods combined with technical skills in support of engineering activities. It can be said to lie in the occupational area between the craftsman and engineer, but closer to the work of the engineer.

Now that the demand curve for engineering services seems to be sharply upward, the outlook for engineering technology graduates could hardly be more favorable. At present, some one million technicians are employed in industry, of whom approximately half have had no formal education beyond high school. By 1980, employment activities may justify educating some 50 percent of student technicians to the associate, or two-year-degree, level, and another 25 percent to the baccalaureate level.

One important step in recent years has been the formal recognition, through ECPD accreditation, of four-year programs in engineering technology. The first such program was accredited in 1967, and by 1973, 24 schools had 81 programs accredited to award bachelor's degrees in engineering technology. Correspondingly, the number of graduates from these programs rose from 30 in 1968 to 2161 in 1973, a significant increase, but far short of the industrial requirements.

Several forces appear to be influencing the future of engineering technology education. For one, the number of two-year institutions of higher education such as community and junior colleges has increased rapidly in recent years, with a concommitant increase in enrollment from 451 333 in 1960 to almost 2 million in 1974—and it is projected that more than 2 million students will be enrolled for degree-credits in two-year institutions by 1980. Other factors include the emergence of industrial technology programs from the area of industrial-arts teacher education, the trend to extend engineering education technology programs to four years, and the changes in the sociotechnological environment itself.

ferences in the various estimates of the number of engineers are due in large part to the way in which the data are collected. For the census, each respondent was asked to identify the occupation of each member of the household. The Department of Labor, which classifies 1 066 000 persons as engineers, asked employers how many engineers they employ.)

The Engineering Manpower Commission, which has adjusted the census figures to separate nonengineering and engineering graduates, estimates that in 1970 there were about 1 070 000 college graduates whose highest degrees were in engineering, of whom only 582 000 are working in the occupation of engineering as defined by the Department of Labor. The National Science Foundation estimates that in 1970 there were approximately 8000 black engineers in the U.S. Although the figures vary depending upon the definition of engineer used, the number of black engineers in the United States is estimated at around 1 percent, and the percentage of other minority-group engineers is also small; women account for some 1.6 percent of engineers.

As for new entrants into the profession, in 1970 only 0.9 percent of the bachelor's degrees in engineering were awarded to blacks, and 0.8 percent to women. Based on these statistics, it is unrealistic to hope that many minority-group members or women will rise to leadership positions in industry within the next decade or so. It takes 15 to 20 years to become an industrial leader. If only 1 percent of the engineers entering industry in 1974 are women or minority-group members, it is reasonable to assume that only a corresponding percentage will be available for top positions in 1990.

The future, however, is not as bleak. In 1973, blacks and women were each awarded about 1.2 percent of the total bachelor's degrees in engineering. Judging by present undergraduate enrollments, by 1977 women should be receiving almost 3.0 percent of these degrees and blacks 2.8 percent (Fig. 5).

Another change that is taking place is that more schools are graduating black engineers. During the past 20 years at least half of the black engineers in the United States attended the six black-oriented engineering colleges (Howard University, Southern University, Tennessee State, North Carolina A.&T., Prairee View, and Tuskegee), but now most universities are increasing their black enrollments.

The same finding in true for women engineers. The Massachusetts Institute of Technology, which granted its first engineering degree to a woman in 1902, has graduated a sizable percentage of all women engineers to date, and now has 129 women in its freshman class—or 14 percent of its first-year enrollment.

For further reading

Occupational Manpower and Training Needs (bulletin), Bureau of Labor Statistics, U.S. Dept. of Labor (to be published).

Scientific Human Resources: Profiles and Issues, NSF 72-304, available from U.S. Government Printing Office, Washington, D.C.

Projections of Educational Statistics to 1980–81 (1971 ed.); *Projections of Educational Statistics to 1982–83* (1973 ed.), U.S. Office of Education, available from U.S. Government Printing Office, Washington, D.C.

Brode, W. R., "Predictions for future scientific and manpower supply and demand, based on a saturation model," *Science*, vol. 173, no. 3993, 1971.

"Report of the Committee on Engineering Education After the War," *J. Eng. Ed.*, vol. 34, p. 604, May 1944.

Engineering Technology Education Study Final Report, Jan. 1972, available from the American Society for Engineering Education, Washington, D.C.

Characteristics of Excellence in Engineering Technology Education, 1962, available from the American Society for Engineering Education, Washington, D.C.

Occupational Characteristics, 1970 Census, PC(2)-7A, U.S. Government Printing Office, Washington, D.C.

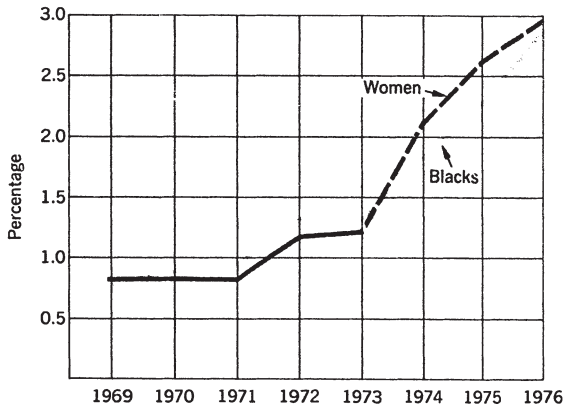
Bulletin No. 22, Engineering Manpower Commission, Aug. 1972.

Engineering and Technology Enrollments, Fall, 1972, Engineering Manpower Commission, Mar. 1973.

Grayson, L., "Trends in engineering instruction: 1974," *Eng. Ed.*, fall 1974.

Also, for a more complete description of the new engineering technology programs being offered by the various colleges, see the article by Don Mennie entitled "The B.E.T.: engineer or supertechnician?" in this issue, pages 60–63.

[5] Percentages of bachelor's degrees in engineering awarded to women and to blacks, projected to 1976.



I. Distribution of U.S. engineers by ethnic group and sex

Ethnic Group	Men	Women	Percent of U.S. Population	Percent in Engineering
White	1 199 811	19 697	—	—
Black	14 198	757	11.1	1.19
Spanish origin*	17 237	298	4.4	1.40
American Indian	1 103	63	0.39	0.09
Japanese origin	6 494	132	0.29	0.53
Chinese origin	9 038	82	0.21	0.73
Filipino	2 142	35	0.17	0.17
Total men†	1 236 160		—	—
Total women†		20 775	51.3	1.65

* As "Spanish origin" does not specify race, all persons included here are also included in the race categories.

† Totals include other races not shown separately.

Moreover, more than a dozen institutions have more than 50 women engineering students each, and most engineering colleges have at least a few.

Other recognized minority groups—such as American Indians and those of Spanish origin—are also underrepresented in engineering in relation to their percentage of U.S. population, but little attention has been paid to their recruitment. It should be noted that not all minority groups in the U.S. are underrepresented in engineering. Filipino-Americans are proportionally represented, and persons of Oriental background are overrepresented in comparison with their respective percentages of the total population. The distribution of U.S. engineers, by ethnic group and sex, as determined by the 1970 Census, is given in Table I.

The demands of social justice, the requirements for industry to employ more minority persons in an effort to eliminate discrimination, the need for minorities and women as engineers who may have special outlooks and concerns when dealing with sociotechnical problems, such as those of the "inner city" where many minority persons have their roots, and the very pragmatic need to increase the overall number of engineers available in the expectation of a future shortage are all compelling reasons to induce women and minority-group members to enter the profession.

Projection 6: Efforts to recruit minorities into engineering will continue. Although the short-term projection for increasing the number of blacks in engineering is encouraging, drawing substantial numbers of blacks into the profession will be difficult and slow. The percentage of engineering graduates who are black probably will not exceed 5 percent by 1984.

But obstacles remain

Beyond discrimination, one difficulty that many blacks will face in choosing engineering as a career will be to overcome the effects of a heritage of pover-

The supply of engineers

The number of degrees awarded in electrical engineering in the United States since 1955 are given in the accompanying illustration. In considering these data, it should be recognized that the total supply of electrical engineers is approximated by the number of students receiving the B.S. degree. This is true because those who obtain M.S. and Ph.D. degrees in electrical engineering in most cases have been previously counted at the B.S. level, and those who enter the U.S. labor force after graduate work in electrical engineering without a U.S. undergraduate baccalaureate in electrical engineering, such as B.S. graduates in physics, etc., as well as many students from other countries, are roughly counterbalanced by the number of B.S. electrical engineers who leave engineering to carry on graduate work in other fields.

Surprisingly, the total supply of electrical engineers as measured by B.S. degrees has remained within 10 percent of 11 300 per year for every year beginning with 1959, irrespective of the "shortages" and "oversupply" as perceived by the general public and by the engineering profession at various times in this span of years.

The number of students who have carried their training in electrical engineering to the M.S. and Ph.D. levels is seen to have increased greatly since the mid-1950s, and now is about 38 and 8 percent, respectively, of those who were graduated with B.S. degrees at an appropriate earlier period. It is thus apparent that the average level of training of the young people entering professional work in electrical engineering has been steadily improving.

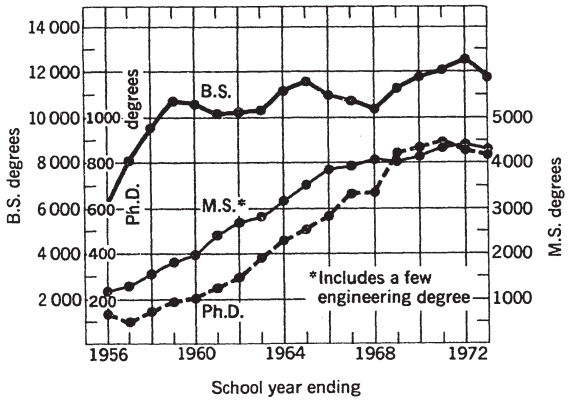
What can we expect looking ahead into the next decade? On the basis of past performance and present trends, there is no reason to anticipate that the number of electrical engineers who will graduate at the B.S. level will change drastically in the foreseeable future. Although there will be a temporary drop in 1975 and 1976 to something like 10 000 or a little less, because of low freshman enrollments in engineering in 1971 and 1972, it seems almost certain from present trends that by the early 1980s the numbers will be back again to approximately 11 000.

At the graduate level, some changes can be expected. The number of master's degrees appears to be leveling off at around 40 percent of the B.S. output, and can be expected to remain at this high output indefinitely. This implies that M.S. training will become increasingly regarded as the standard preparation for those who plan to go into the general practice of technical engineering. It is anticipated that the character of M.S. training will continue in the pattern now being followed by the leading schools—namely, a program of instruction that provides a sound, broad preparation for the many-faceted and increasingly technological field of electrical engineering, and including growing attention to related societal problems.

It is to be expected that the Ph.D. output in the years ahead also will level off at about the present numbers—to around 900 to 1000, or nearly 10 percent of the B.S. output. However, Ph.D. training during the next decade is likely increasingly to represent broadly based preparation for the general practice of technical engineering at a very high level, rather than an overwhelming emphasis on a narrow specialty, as is so often now the case. This change is probable because, as compared with the recent past, there will be fewer jobs in academic institutions, in defense, and in space, and hence less need for research specialists. Thus, the Ph.D. will tend to be a degree that is sought by individuals who want better training than that represented by the standard M.S. program, and who wish a broader education that will prepare them for whatever areas of electrical engineering are in demand in the marketplace, and to enter challenging new areas that may open up in the future.

Will there be jobs for these engineers? The answer is an unqualified yes! It can be safely predicted that by 1976, or perhaps sooner, the United States will be facing a shortage of engineers, and those who are now being trained for the profession will be offered a choice of attractive positions at attractive salaries.

Frederick E. Terman
Stanford University



ty. Students from impoverished areas will continue to lack inspirational models, as well as the essential high-school preparation in mathematics and science that is necessary to complete undergraduate engineering programs sucessfully. Industry may be anxious to attract minority engineers, but it cannot afford to hire or promote to responsible positions any sizable number of poorly qualified people without jeopardizing its competitive position in national and international markets.

Projection 7: Women also will continue to be encouraged to pursue careers in engineering. In this case, from the viewpoint of the profession the efforts will be more successful, and the number of engineering graduates who are women could rise to about 10 percent by the mid-1980s.

With regard to women, there is a large population base from which to draw, and one that in most cases has had adequate high-school preparation. Although many women have not emphasized mathematics and science in their high-school studies, they are academically qualified to do so, and probably will with proper counseling and guidance.

The classic view of engineering as a "man's field" will change, and women who wish to combine a career with raising a family will find industry more willing to provide the opportunity to do so. Many of these women will encounter some difficulty, however—keeping their technical knowledge up to date, and being able to take the necessary time on a daily basis to work at building a successful professional career. The rapidity with which the state of the art advances makes it difficult for a woman to leave the field for a year or more to attend to family matters, and then return to the type of position she left. Also, many engineering positions require a continuity of full-time effort, and will not allow for the turnover of key personnel in the middle of a project. Engineering, with a few exceptions that occur primarily in the area of consulting, does not provide the flexibility in choosing work schedules or part-time employment that some of the other professions, such as law and medicine, do.

Educating the educators

There are many reasons why the changes in engineering education that have been described are taking place. These reasons are as much, and perhaps more, a result of changes in U.S. society and national attitudes as they are of the changing demands for technology. As a nation, the United States has avowed disenchantment with war and with the weapons of war that have been produced by modern technology.

The U.S. has begun to shift its priorities away from defense and toward human and social problems. A man has been landed on the moon, and now that this has been accomplished, the space race no longer is of paramount importance. As a result, there has been a significant decrease in Federal funds available for space activities and an increase in funds for applying science and technology to such domestic problems as housing, transportation, health care, energy conservation, and ecology and the pollution of our air and waters. Many young people have evinced an interest in helping the less fortunate among us, and they are thus seeking careers—such as law and medicine—in which they believe they can better achieve their goals.

It takes a long time—four to ten years—to produce an engineer. The engineering graduate of 1974 probably made the decision to enter the field in the mid- to late 1960s, at a time when the national interests and opportunities in engineering were very different from today. In contrast to the time that it takes to train engineering manpower, many of the factors that control the utilization of that manpower can change rapidly, sometimes in a matter of months. Federal decisions to initiate, expand, or reduce broad programs can be implemented within a relatively short time—as illustrated by the start of the space program in the 1950s, the subsequent reduction in that program, and the rapid and more recent development of national programs dealing with environmental quality and with energy.

A study of the future depends on past trends, and on changes that are expected to take place in the trends or in the key factors that affect the trends. Such a study, of course, can be made with more confidence, although not necessarily more accuracy, when the situation is relatively stable—when the trends have existed for a long time and are not likely to change during the period being studied. This is not true of engineering today.

The length of time required to produce engineering graduates coupled with the volatility of the demand for engineers underscore the importance of making engineering education more responsive to changing priorities so that demand can be more nearly matched with supply.

Several projections for the future have been discussed. How accurate they prove to be will be determined to a large extent by the way in which U.S. attitudes and needs change over the remainder of the decade, and by the way in which engineering educators and those in a position to influence engineering manpower move to meet those needs.

Lawrence P. Grayson (SM) is currently with the National Institute of Education (NIE), where one of his duties is to manage a $15 million program using the NASA satellite ATS-F to bring education to rural areas of the Rocky Mountain, Alaska, and Appalachia regions. Since receiving the B.E.E., M.E.E., and Ph.D. degrees in electrical engineering from the Polytechnic Institute of Brooklyn, Dr. Grayson has taught in the EE Departments at both The Johns Hopkins University and Manhattan College; he has spent 14 months under sponsorship of a Ford Foundation faculty grant at IBM's Thomas J. Watson Research Center, working in the area of computer-assisted instruction; and, in 1969, he joined the U.S. Office of Education, where he was director of the Division of Technology Development until he transferred to NIE in 1973. His IEEE activities include membership on the Education Group Advisory Committee and service as program cochairman for the 1973 Frontiers in Education Conference and as chairman of the Baltimore Section's Automatic Control Group. He also is a vice president of the American Society for Engineering Education, and chairman of its Council for Teaching and Learning.